Age, Growth, Mortality, and Fecundity of Yellow Perch in Yeopim River, Albemarle Sound, North Carolina

Eric E. Fitzpatrick,[1] *East Carolina University, Howell Science Complex Greenville, NC 27858*

Anthony S. Overton, *East Carolina University, Howell Science Complex Greenville, NC 27858*

Abstract: Yellow perch (*Perca flavescens)* is recognized as a widely distributed and valuable freshwater species, but few reports have described estuarine populations in coastal river systems. We conducted a two-year study to assess the age, growth, mortality, and fecundity of yellow perch in Albemarle Sound, North Carolina. Fish were collected ($n = 2{,}674$) in 2005 and 2006 (January–February) by trap from Yeopim River, Yeopim Creek, and Bethel Creek. Yellow perch ranged in age from 1–9 years, and the catch was dominated by age-2 fish (82.1%) in 2005 and age-3 fish (84.2%) in 2006. Lengths ranged from 130 to 292 mm TL ($\text{mean}_{\text{female}} = 231.1 \pm 3.3$ S.E. mm TL; $\text{mean}_{\text{male}} = 177.8 \pm 12.1$ mm TL). Length distribution and age frequency data suggest that 2003 was a successful year class for yellow perch in Albemarle Sound. Instantaneous total mortality (Z) was 0.35 (annual mortality 30%), and was similar to estimates from Chesapeake Bay. Length at age data were fitted to a Von Bertalanffy Growth Function ($L_\infty = 351.0$, $K = 0.197$). Fecundity ranged from 5,000 to 45,000 eggs/female with a mean of 15,135 ± 9,068 S.E. eggs/female. Fecundity estimates were lower than estimates from the Great Lakes but were similar to fish in Chesapeake Bay.

Key words: age, growth, mortality, fecundity, yellow perch, North Carolina

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Yellow perch (*Perca flavescens*) inhabits a wide geographical area throughout North America ranging from Canada through the southeastern United States (Carlander 1977). Yellow perch is generally considered a freshwater species; however, it is also found in coastal rivers and estuaries along the Atlantic and Gulf coasts the United States (Carlander 1977). The yellow perch fishery is an important economic resource for both recreational and commercial stakeholders. Yellow perch is highly exploited with average annual landings of 1,180 mt per year since 1950 and market values increasing from USD$0.17 per lb (1950–1984) to $1.71 per lb (1985–2005) (National Marine Fisheries Service 2007).

Population and abundance indices for yellow perch frequently fluctuate throughout its natural range (Doan 1942, LeCren 1955, Forney 1971). These fluctuations are because of multiple factors including exploitation rates, the availability of food, and abiotic factors. Fortunately, yellow perch populations persist from year to year where strong year classes are generated when conditions are favorable (LeCren 1955). Without these strong year classes, populations could decline below sustainable levels. By examining the factors that influence year classes such as truncating age classes, decreases in food availability, and variability in recruitment, managers can begin to understand yellow perch population dynamics.

Developing accurate estimates for age composition, recruitment, and year class strength are fundamental principles for fisheries management. These data allow managers to identify strong year classes, predict mortality using catch curves, and identify individual growth patterns. Most research has addressed the life history, biology, and management of yellow perch in freshwater systems common in its northern range (Sztramko and Teleki 1977, Hayward and Margraf 1987, Graeb et al. 2006, Isermann et al. 2007). For example, the age composition of yellow perch from a northern oligotrophic lake demonstrated that a single cohort constituted the majority of individuals in the population for up to five years (Sanderson et al. 1999). In other studies, recruitment was evaluated using fecundity to assess the contribution of individual females to the stock and was correlated with the age, size, and time of spawn for yellow perch (Sztramko and Teleki 1977, Lauer et al. 2005).

Currently in Albemarle Sound, North Carolina, there is no size limit or creel limit for the yellow-perch recreational and commercial fishery. Yellow perch are usually targeted by fishermen for six to eight weeks (January and February) when they enter the shallow water tributaries to spawn. Following spawning, the adults move to deeper waters in Albemarle Sound proper and remain there until the following spawning season. They are rarely targeted during the remainder of the year and are rarely found in the bycatch of other commercial fishing operations.

Information describing yellow perch population dynamics in

1. Current Address: North Carolina Division of Marine Fisheries, 943 Washington Square Mall, Washington, NC 27889

estuarine environments is sparse and most published research has focused on yellow perch in Chesapeake Bay (Muncy 1962, Mansueti 1964, Tsai and Gibson 1971). To effectively manage yellow perch in estuarine systems, there is a need to understand its biology and general life history. The goal of this study was to investigate the life history of yellow perch in Albemarle Sound, North Carolina. The specific objectives of this study were to collect fisheries-independent data to describe patterns in growth, fecundity, and condition of yellow perch inhabiting a low salinity estuarine environment. This study represents a valuable contribution to fisheries management in North Carolina because of the scarcity of information about yellow perch in Albemarle Sound.

Methods

Study Area

Albemarle Sound is approximately 2,770 km^2 with a length of 90 km and an average width of 11 km (see Haeseker et al. 1996). The average depth is 4.6 m and varies with wind direction and lunar tidal fluctuations (Giese et al. 1985, Pietrafesa and Janowitz 1991). Several coastal rivers such as the Alligator, Chowan, Roanoke, and Yeopim discharge into the sound. Sediments within Albemarle Sound are typically sand, silt, and clay (Haeseker et al. 1996). The western portion of Albemarle Sound is characterized as a freshwater environment (salinity range from 0.0–0.2 ppt) which is primarily influenced by freshwater input from the Roanoke River. Conversely, the eastern region of Albemarle Sound has a higher salinity (range of 2.0–15.0 ppt) as a result of saltwater intrusion from Oregon Inlet, the only connection Albemarle Sound has to the Atlantic Ocean (Giese et al. 1985).

Sample Collection

Yellow perch were captured during January and February 2005 and 2006 in three tributaries of Albemarle Sound: Yeopim River, Yeopim Creek, and Bethel Creek (Fig. 1). Sampling was conducted with the assistance of experienced commercial fishermen using modified perch traps ($n = 50$) (El-Zarka 1959, Murphy and Willis 1996). These traps were commonly used by commercial fisherman in Albemarle Sound, although fyke nets were also frequently used for commercial harvests. Perch traps were constructed of 2.5-cm wire mesh and measured 121 cm long with a 53.3-cm diameter. The traps had a unidirectional 45.7-cm diameter funnel entrance into the trap. This funnel shape reduced to 10.2 cm in the middle of the trap making it difficult for fish to escape. Traps were fished at 1.8 m depths generally placed within 5 m of structure including logs, stumps, tree limbs, and drop-offs. The location of these structures was based on advice provided by commercial fishermen. The traps were set from two to nine days depending on weather conditions. In 2005, we made 16 sampling trips and collected 2,245 yellow perch. The 2006 sampling season was shortened because of weather and logistical problems and consisted of five sampling trips and the capture of 429 fish.

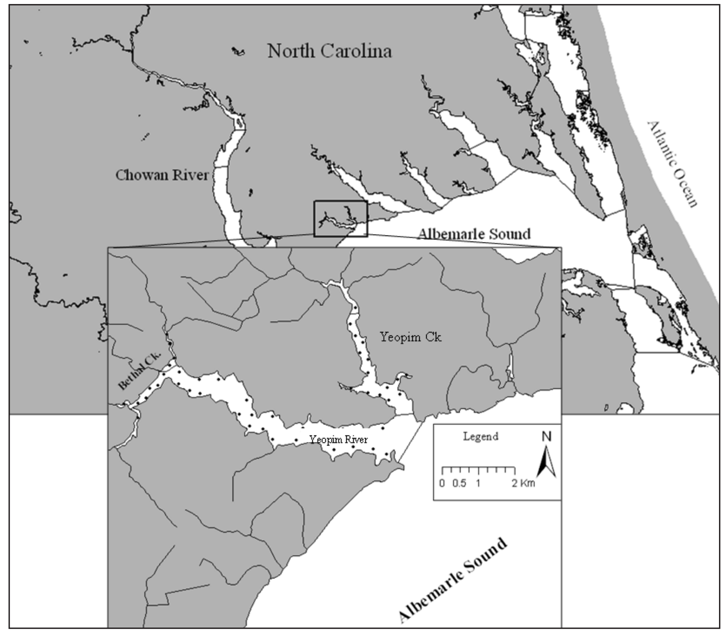

Figure 1. Map of study area in Yeopim River, Yeopim Creek, and Bethel Creek in Albemarle Sound, North Carolina. The closed circles represent locations where perch traps were placed.

Yellow perch were recovered from the traps, counted, and a sample was kept for further analysis. If a trap had five or less yellow perch, all yellow perch were retained for laboratory analysis. If more than five fish were in the traps, a random sample was taken and consisted of 6 to 40 individuals. All fish in the sample were weighed, measured, euthanized, placed in labeled plastic bags on ice, and transported back to the laboratory for analysis. The mean lengths ($\log_{10}$ transformed) of males and females were compared using an analysis of variance (ANOVA; $P < 0.05$) (SAS 2000).

Age, Growth, and Mortality

Otoliths were removed for age determination (Bulow et al. 1987). In the laboratory, fish were cut longitudinally through the top of the skull and through the brain cavity (Murphy and Willis 1996). The otoliths were removed and stored in labeled envelopes. One sagitta (right) per fish was embedded in epoxy resin, and a thin transverse was cut using a Buhler slow-speed saw (Secor et al. 1991). Thin sections were placed under a dissecting microscope for examination. Annual rings were counted and measured, to generate age distribution. Using image analysis software (Image Pro Discovery), annual rings were counted then measured to the nearest micron for back-calculation of length-at-age. Two readers examined each otolith and there was 96% agreement on the age estimates. An age–length key was developed to assign ages to unaged yellow perch.

Total instantaneous mortality, Z, was estimated by the absolute value of the slope of the descending right limb of the plot of log age frequency by age (catch curve) (Ricker 1975). Because age-1 fish were not fully recruited to our sampling gear, catch-curve analysis was limited to age-2 and older yellow perch.

Growth was expressed using a von Bertalanffy growth function (VBGF) fitted to the length at age data . The equation is stated as

$$L_t = L_\infty (1 - \exp^{(-k(t-to))})$$

where L_∞ = maximum theoretical length, K = the Brody growth coefficient, and t_o = theoretical age in years when length = 0 (Ricker 1975). The VBGF was fit by nonlinear regression to length-at-age data (SAS 2000).

Fecundity—Fecundity was determined ($n = 37$) by analyzing egg abundance within female perch. We used a volumetric method which involved counting 100 eggs, measuring the volume of these eggs, and then measuring the volume of the entire egg (Braum 1978, Snyder 1983).

Condition Indices—Yellow perch condition was estimated using relative weight (W_r) and Fulton's condition factor (K) (Murphy and Willis 1996). These indices were calculated with morphometric data and the following equations:

Relative Weight: $W_r = (W/W_s) \cdot 100$

Fulton's Condition Factor: $K = (W/L^3) \cdot 100{,}000$

where W is the wet weight of the fish , Ws is the length-specific standard weight, and L is the length. Relative weight uses 100 as a level that is representative of a fish considered in "good" condition (Anderson 1980, Murphy and Willis 1996). Condition factor and relative weight data were tested by means of analysis of variance (ANOVA; SAS PROC GLM) with an a priori type-I error level of 0.05 (SAS 2000). If ANOVA indicated significant differences ($P < 0.05$), the least-significant-difference test was used to separate means. All percentage and ratio data were transformed to arcsine values before analysis (Zar 1999). Untransformed data are presented to facilitate interpretation.

Results

Size and Age Distribution

The allometric weight–length relationship for each sex was determined (Fig. 2). Females were heavier at a given length than males. Lengths of yellow perch collected ranged from 130 to 292 TL mm, ($mean_{female} = 231.1$ TL mm, S.E. ± 3.3; $mean_{male} = 177.8$ mm, S.E. ± 12.1). Males were significantly smaller in length than females in 2005 (ANOVA, df = 596, $F = 14.72$; $P < 0.0001$; Fig. 3).

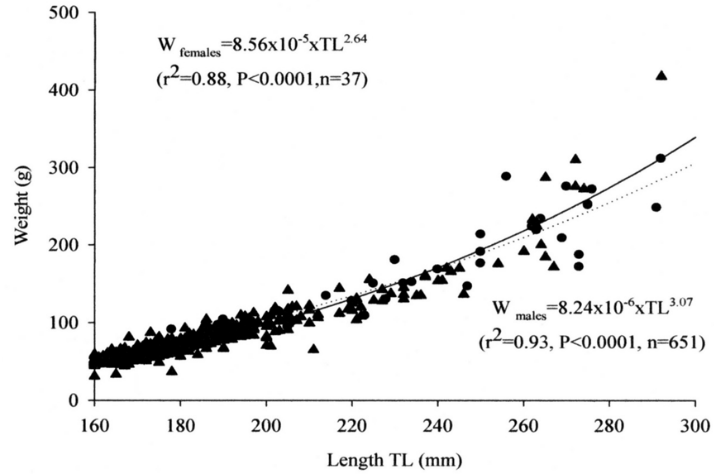

Figure 2. The relationship between total length and body weight (g) for yellow perch males (dotted line and triangles) and females (solid line and closed circles) collected in Albemarle Sound, North Carolina, in 2005 and 2006. The regression equation for the males (lower right) corresponds to the lower curve; that for females corresponds to the upper curve.

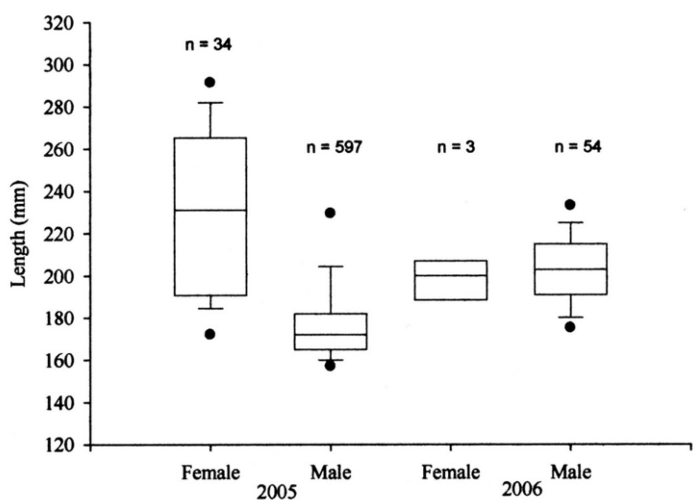

Figure 3. Box plot of mean lengths (mm) for yellow perch captured from Yeopim River, Yeopim Creek and Bethel Creek, Albemarle Sound, North Carolina, in 2005 and 2006. Means lengths are represented by the solid line within each box. The solid circles represent the 5th and 95th percentiles.

The length distribution of yellow perch was wider in 2005; however, the length distribution shifted to larger fish in 2006 (Fig. 4). Male yellow perch between 150 and 180 TL mm made up 59% of the sample, while fish >200 TL mm (males and females) represented 16 % of the overall sample. Males accounted for 95% of the total catch resulting in an 18:1 male to female sex ratio. Yellow perch between 200 TL mm and 250 TL mm generated a sex ratio of 7:1 and 1:1 for fish >250 TL mm.

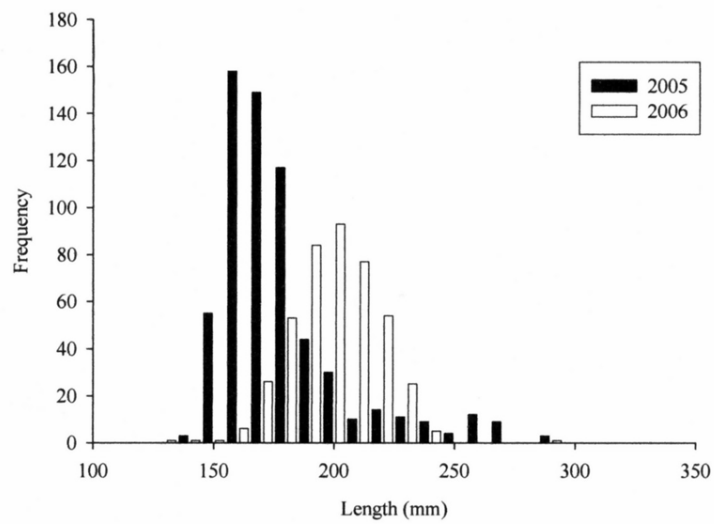

Figure 4. Length frequency distribution of yellow perch captured from January to March 2005 ($n = 631$) and 2006 ($n = 245$) in Yeopim River, Albemarle Sound, North Carolina.

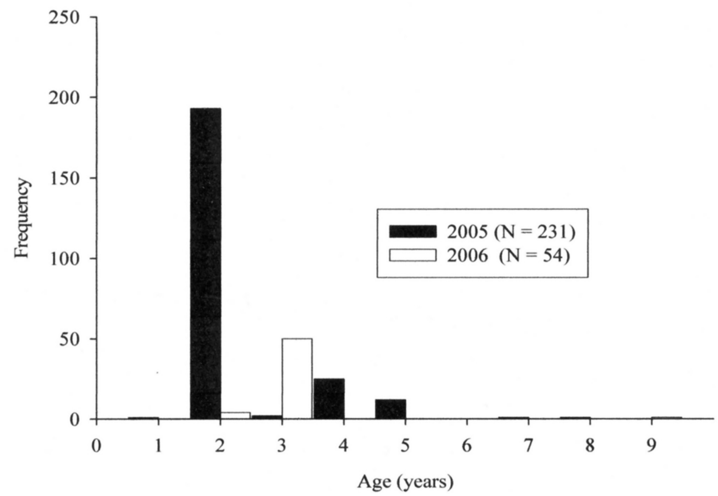

Figure 5. Age-frequency distribution for yellow perch captured from Yeopim River, Yeopim Creek, and Bethel Creek, Albemarle Sound, North Carolina, 2005 and 2006.

Growth and Mortality

The ages of yellow perch ranged from 1–9 years. Age-2 (82.1%) yellow perch dominated the sample in 2005 and age-3 (84.2%) in 2006. In 2005, few age-3 and age-6 yellow perch were collected, and age-4 and age-5 fish made up almost 16% of the sample (Fig. 5). Length fitted to VBGF generated:

$$L_t = 351.0 \cdot (1 - e^{-0.197(t - 1.59)})$$

The parameters, L_{∞}, K, and t_{0}, produced a standard length (TL mm) at age for yellow perch (Fig. 6). Instantaneous total mortality rate (Z) for 2005 was 0.35 (annual mortality, 30%) (Fig. 7).

Nutritional Condition

Relative weight (W_r) ranged from 56.4 to 116.5 (mean 92.4 ± 18.3 S.E.). Mean condition for females was 91.7 (± 9.7) and for males was 90.1 (± 14.4). Twenty-six percent of females and 15% of males had a W_r above 100. There was no significant difference in W_r between male and female yellow perch (ANOVA, df = 630; $F = 9.53$; $P = 0.406$). Similar results for Fulton's condition factor were observed where mean K for females was 1.29 (S.E. ± 0.03) and 1.25 (S.E. ± 0.01) for males. Statistical analysis showed no significant difference in W_r and K between 2005 and 2006 sampling seasons (W_r, df = 320; $F = 9.26$; $P = 0.23$), (K, df = 320; $F = 1.46$; $P = 0.22$).

Fecundity

Female yellow perch from ages 2–5 ($n = 37$) were collected for the fecundity analysis. We found a positive linear relationship (df = 36, $F = 38.45$, $P < 0.001$, $r^2 = 0.54$; Fig. 8a) between fish length and fecundity:

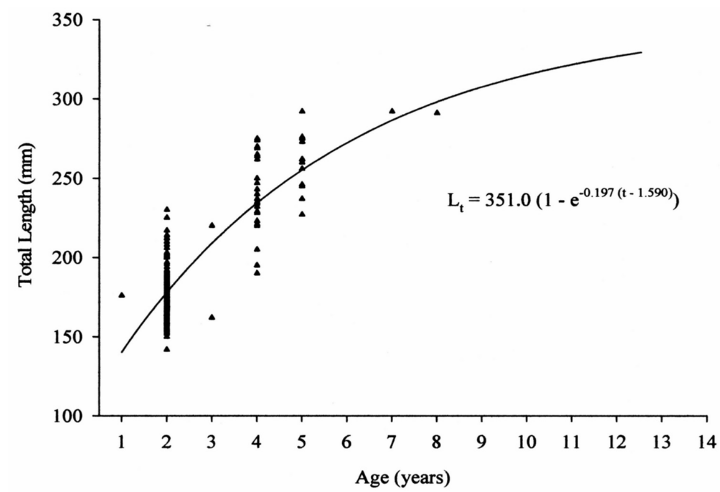

Figure 6. Von Bertalanffy growth equation fitted to the observed length at age data for both sexes for yellow perch captured from Yeopim River, Albemarle Sound, North Carolina.

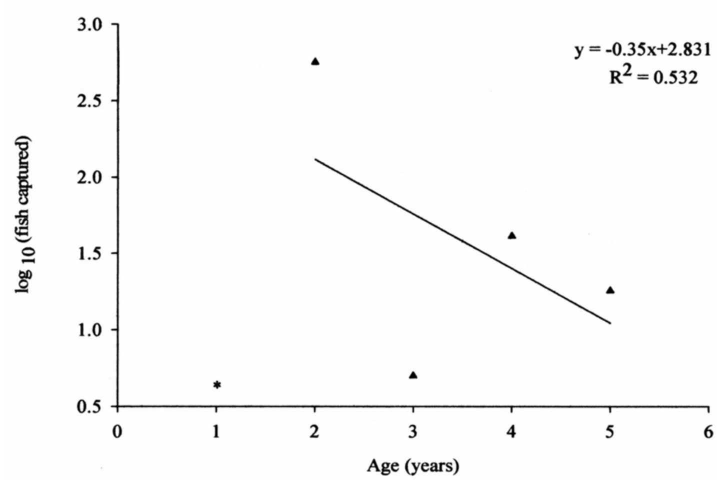

Figure 7. Instantaneous total mortality (Z) for yellow perch captured in spring, 2005 from Yeopim River, Yeopim Creek, and Bethel Creek, Albemarle Sound, North Carolina. * Age-1 fish were not included in the analysis.

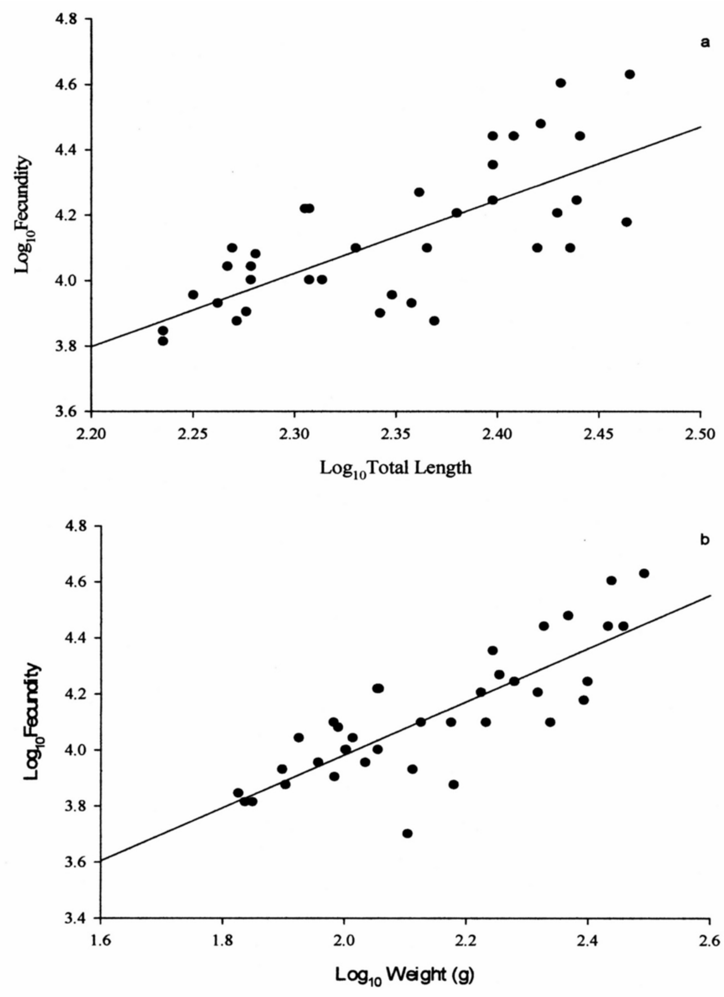

Figure 8. Relationship between total length (a), weight (b), and fecundity of yellow perch collected in Yeopim River, Albemarle Sound, North Carolina, 2005.

$$log_{10}F = -2.61 + 2.24 \cdot log_{10}TL$$

Fecundity ranged from 5,000 to 45,000 eggs/female with a mean of 15,135 (S.E. ± 9,068) eggs. The fecundity predicted by the linear regression over the observed length range was 6,646 eggs for a 172-TL mm fish and 26,368 eggs for a 292 TL mm fish. We also found a strong positive linear relationship (df = 46, $F = 508.73$, $P < 0.001$, $r^2 = 0.92$; Fig. 8b) between fish weight and fecundity:

$$log_{10}F = -9.49 + 2.66 \cdot log_{10}W$$

Discussion

Length distribution data and age frequency data collected in 2005 and 2006 suggested that 2003 was a successful year class for yellow perch in Albemarle Sound. In 2005, length distribution was dominated by one major length category (160 TL mm). Data collected by North Carolina Division of Marine Fisheries (NCDMF) provided supporting evidence of this dominant year class. Juvenile abundance survey data collected using seines and trawls throughout the entire Albemarle Sound showed a distinct peak of juvenile yellow perch abundance for 2003 (M. Loeffler, NCDMF, personal communication). Additional age data collected in 2006 confirmed the dominant 2003 year class. Analysis of otoliths showed that 95% of the 2006 sample consisted of age-3 yellow perch. This 2003 year class may have been strongly influenced by increased food availability during the first summer after spawning or a number of other environmental factors (Forney 1971).

Instantaneous total mortality (Z) was estimated at 0.35. This estimate was similar to estimates for yellow perch from Chesapeake Bay in 2001 that ranged from 0.10 and 0.46 (Sadzinski et al. 2005). Age-2, age-4, and age-5 yellow perch made up 85% of the fish sampled. Age-1 individuals were not fully recruited to the gear and few age-6+ yellow perch were captured by our gear. Only one age-3 fish was present in our samples in 2005. This provides evidence for a poorly recruited year class form 2002. Additional data from NCDMF juvenile sampling suggests that recruitment for yellow perch in Albemarle Sound was low in 2002. This age structure is similar to yellow perch population experiencing heavy exploitation (Goedde and Coble 1981).We attempted a second estimate of Z using age frequency data from 2005 and 2006 to follow the 2003 cohort. By following the 2003 cohort from 2005 and 2006, the estimated instantaneous total mortality $Z = 0.16$. This post-hoc analysis was conducted to verify the estimate of Z using catch curve analysis. The Z value attributed to the 2003 cohort analysis suggests a lower Z than was estimated from the catch curve. The catch curve estimate included only one age-3 individual which caused the estimate of Z to be lower than the actual Z. By following the 2003 cohort, procedural errors attributed with catch curve analysis are reduced and allow for a more precise estimate of Z.

Von Bertalanffy Growth analysis estimated L_∞ was larger than those found in Lake Erie and in Northern Canada (Table 1). The

Table 1. Von Bertalanffy growth function coefficients (L_∞ and K) and relative weight estimates from published studies throughout the United States and Canada. Values are listed in order of increasing latitude.

Location	Source	L_∞, K	Mean Wr
Georgia	Willis et al. 1996	–	63
Albemarle Sound, NC	Current Study	350.3, 0.197	90
Virginia	Willis et al. 1996	–	82
Chesapeake Bay	Muncy 1962	–	83
Iowa	Willis et al. 1996	–	94
Pennsylvania	Willis et al. 1996	–	81
Vermont	Willis et al. 1996	–	84
Lake Erie	Vaughan 1980	260.4, 0.437	–
Lake Saint Louis, Canada	Willis et al. 1996	–	96
Northern Canada	Fortin and Magnin 1972	258.6	–

initial summer following spawn is the most important time for yellow perch growth (Mills and Forney 1981). This period accounts for the majority of growth occurring for an individual's entire life span. We are unsure of the factors driving the differences in L_∞ among the studies. It is likely that our higher estimate of L_∞ is because of a longer growing season in Albemarle Sound. Female yellow perch grow faster, reaching a higher asymptotic size and maturing at an older age (Craig 1977, Fitzpatrick 2007). Females collected in Albemarle Sound showed similar results. Females must reach this larger size to allocate more energy to oocyte development, which is nearly 15% of total body size.

Sex ratio data of adult fish populations along with estimates of harvest can be useful in predicting levels of mortality for a specific sex. Hoenig and Hewitt (2005) used sex ratio information to examine trends in mortality for lumpfish (*Cyclopterus lumpus)* in Newfoundland. By assuming an initial sex ratio of 1:1, observed sex ratios that are different than 1:1 imply a shift in mortality for that specific sex. This study suggests that sex-specific fisheries can influence mortality rates. The sex ratio in our study was 18:1 (males to females) for all fish and decreased to 1:1 for fish >250 TL mm. This pattern may be because of gear selectivity of the trap that was used in this study. Yellow perch in the Great Lakes and the mid-western United States have different sex ratio characteristics than stocks in Chesapeake Bay or Albemarle Sound. Colder regions tend to have a more even sex ratio, 1:1 (Rose et al. 1999). From 1992–1996, the sex ratio of yellow perch in Lake Michigan was skewed (more males than female) possibly because of overexploitation of faster growing females (Madenjian et al. 2002). Conversely, in the Southeastern region this ratio is dominated by males. Estimates of this ratio in Chesapeake Bay varied from 2:1 to as high as 7:1 male to female (Piavis 1991). Our data showed that the sex ratios became more stable (1:1) in the larger length categories which may suggest that mortality rate for small males is higher than females. Increases or shifts in the sex ratio are indicative of higher mortality rates for that specific sex (Hoenig and Hewitt 2005).

Fecundity estimates of yellow perch at length in our study were lower than fish from Lakes Erie, Michigan, and Ontario (Sheri and Power 1969, Brazo et al. 1975, Sztramko and Teleki 1977, Lauer et al. 2005). However, our estimates were very similar to fish throughout their southern range (Muney 1962, Clugston et al. 1978). This geographic difference can be attributed to climate variation (Carlander 1977). Fecundity of percid populations can be affected by food availability and growth (Hayes and Taylor 1994). Total weight was a better indicator for fecundity compared to total length in the Severn River (Tasi and Gibson 1971) as well as our data from Albemarle Sound. Because length and weight can be positively correlated to fecundity (Muncy 1962), this suggests that total weight and total length are both good predictors of fecundity (Lauer et al. 2005).

Yellow perch relative weight varies with geographic range (Carlander 1977). Albemarle Sound yellow perch had a mean W_r of 92. Yellow perch in Georgia had lower mean W_r of 63 and Virginia stocks had a mean W_r value of 82 (Table 1). Yellow perch from our study were collected during the spawning period, while Georgia and Virginia W_r data were collected throughout the year. Seasonal differences in the collection of samples probably lead to the differences W_r among studies. Relative weight for Albemarle Sound suggests that smaller fish are healthier and more robust than larger individuals.

Managers must understand the factors that place stocks in jeopardy of overexploitation. Understanding the life history characteristics for yellow perch in Albemarle Sound is critical for the sustainability of this valuable species. We provide evidence that shows that yellow perch in an estuarine setting differs from fish in freshwater environments. These differences must be considered in the management of yellow perch in Albemarle Sound.

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